

Payload Software Integration and Verification (PSIV)
Concept Document

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ABSTRACT

The International Space Station Program concept for Payload Software Integration and Verification (PSIV) is described. The PSIV process, responsibilities, and program provided capabilities are presented.

KEY WORDS

Command and Data Handling

Payload

Payload Software

Suitcase Test Environment for Payloads

International Space Station

Payload MDM

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1. INTRODUCTION

The Space Station provides an environment for scientific investigation and experimentation in both pressurized and unpressurized space settings. Payloads selected to fly on the Space Station, consisting of both software and hardware components, are developed by the Payload Experiment Developer (PED). Prior to launch, each payload will be integrated, verified, and validated individually and as part of the flight complement. Payload Software Integration and Verification (PSIV) is an integral part of this overall process.

1.1 PURPOSE

This PSIV concept document defines the relationship of the PSIV capability to the PED and to the other component parts of the Space Station program involved in payload integration and verification. The unique role and benefits of the PSIV capability are explained. Utilization of the Payload Software Integration and Verification Facility (PSIVF), located at Marshall Space Flight Center (MSFC), and its portable product, the Suitcase Test Environment for Payloads (STEP), is defined. The development approach to achieve the capability is also stated.

1.2 SCOPE

This document defines the PSIV capability for all U.S. controlled payloads requiring direct or indirect interface to the Space Station Command and Data Handling (C&DH) System.

Section 2 describes the PSIV documentation planned for development and its relationship to the program document hierarchy. Section 3 describes the overall integration and verification process and the role of PSIV. Section 4 gives a high-level description of the PSIV capability. Utilization of the PSIV capability is explained in Section 5. A glossary and acronym list are contained in Section 6.

1.3 ASSUMPTIONS AND GROUND RULES

The following assumptions and ground rules have been used in the development of the PSIV concept.

- 1) The Space Station is the International Space Station (ISS) as defined in the Incremental Design Review ISS Data book.
- 2) Marshall Space Flight Center is the payload analytical integrator for the program.
- 3) The Software Verification Facility (SVF) is being developed to conduct ISS software horizontal level integration and verification.
- 4) The Space Station Command & Data Handling (C&DH) architecture is the option 6 architecture defined in the Prime Design Decision Package # 230, updated with PCMs #226 and #239, and illustrated in Figure 1-1.
- 5) The functional flight software architecture, defined by the Prime and Product Group 3 (PG-3), employs a data driven design.
- 6) The software architecture design supporting payload operations utilizes increment dependent data updates / reconfigurations. Following UF-1, the program will transition to a continuous operations, short cycle integration process. Integration and verification processes for these reconfigurations will be as defined in the appropriate Integrated Product Teams (IPTs).

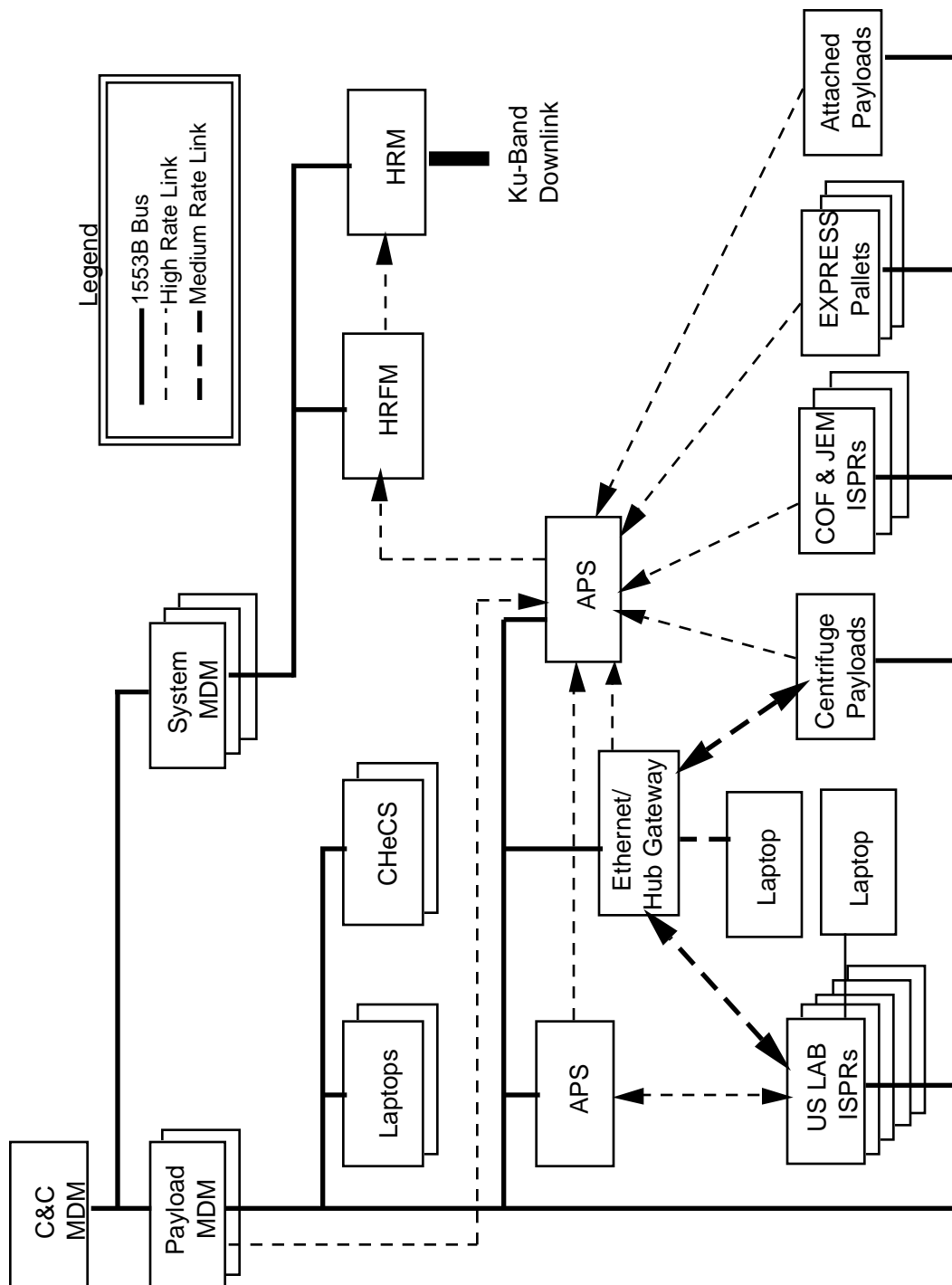


Figure 1-1 C&DH ARCHITECTURE

2. DOCUMENTS

A view of the current program requirements structure along with the documentation planned for PSIV is shown in figure 2-1. The capability to perform payload software integration and verification is established in Volume 1 of the Concept of Operations and Utilization (COU) document. PSIV is explicitly identified in Volume 3 of the COU and in the Ground Segment Specification. The requirements for developing the PSIV facility flow down from the Ground Segment Specification to the PSIV Prime Item Development (PID) Specification and associated Interface Definition Document (IDD).

This PSIV Concept Document will eventually be incorporated into Utilization's Station Program Implementation Plan (SPIP), including Volume 4 Payload Integration, Volume 8 Increment Execution Preparation, and Volume 9 Real Time Operations. The PSIV PID Specification requirements reflect the concepts established in the PSIV Concept Document. PSIV will provide inputs to several of the documents that are part of the ISSA customer documentation tree. The PSIV Facility capabilities will be described in Volume 7 of the ISS Payload Accommodations Handbook. Space Station C&DH and Communications and Tracking (C&T) systems are also described in Volumes 1 through 4 in the Payload Accommodations Handbook for the different payload types. Overall payload verification plans are part of the Payload Verification Program Policy (PVPP) which provides the guidelines and responsibilities for payload software verification. Payload software and C&DH details will be documented in the Payload Data Package accessible electronically from the Payload Data Library (PDL) database. The interfaces between PSIV and other program facilities, such as the Mission Build Facility (MBF), Space Station Training Facility (SSTF) and the Payload Integration and Checkout Facility (PICF), will be documented in PSIV ICD(s).

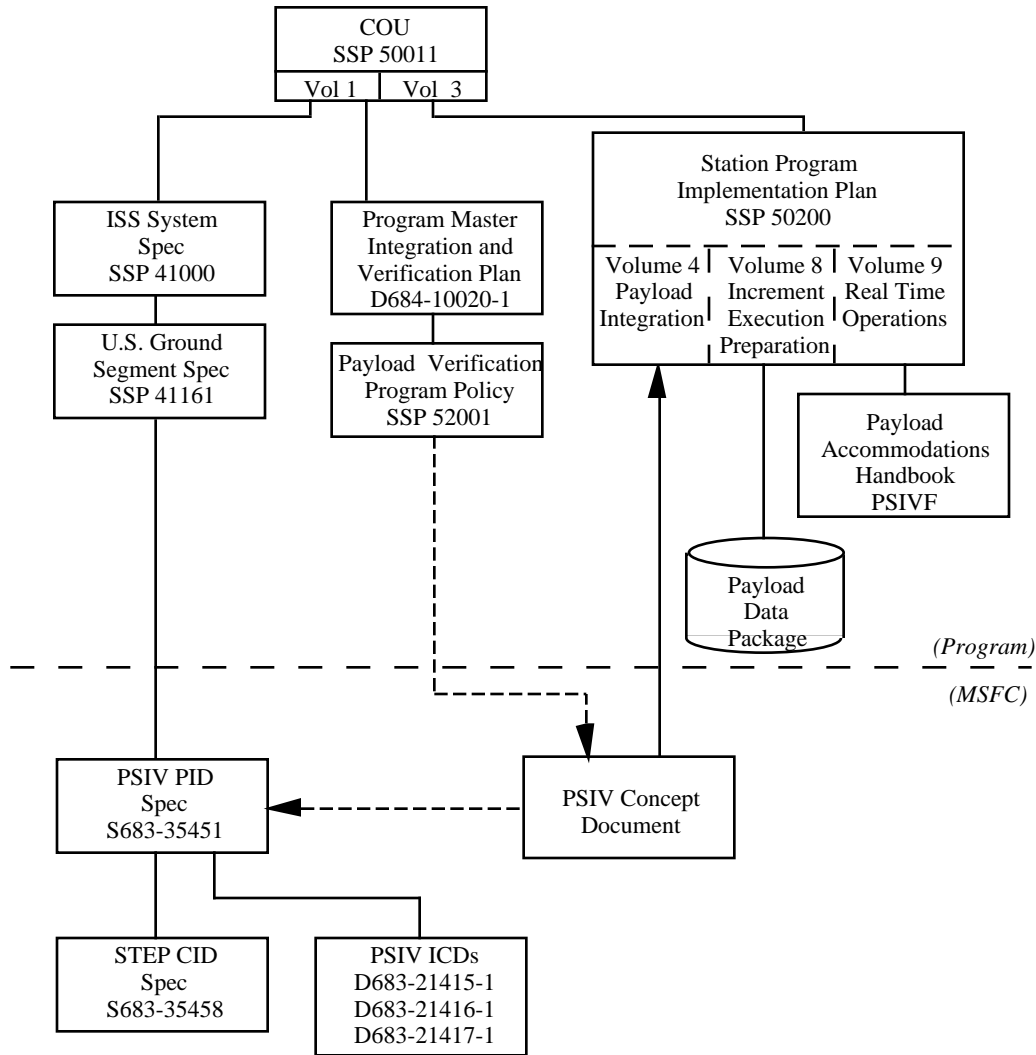


Figure 2-1 PSIV DOCUMENTATION TREE

2.1 APPLICABLE DOCUMENTS

N/A.

2.2 REFERENCE DOCUMENTS

D684-10020-1	Program Master Integration and Verification Plan (PMI&VP)
SSP 52001	Payload Verification Program Policy
SSP 50200	Station Program Implementation Plan
SSP 50011	Concept of Operations and Utilization
SSP 41000	ISS System Specification
SSP 41161	United States Ground Segment Specification

S683-35451	PSIV Prime Item Development Specification
S683-35458	Critical Item Development Specification for the Suitcase Test Environment for Payloads
D683-21415-1	PSIV to Payload Data Library (PDL) Interface Control Document
D683-21416-1	PSIV to Space Station Training Facility/Payload Training Complex (SSTF/PTC) Interface Control Document
D683-21417-1	PSIV to Payload Integration & Checkout Facility (PICF) Interface Control Document
D683-70830-1	PG-3 Payload Systems Development Handbook
S683-70741	Payload Executive Processor CSCI SRS
SW683-70786-1	Payload Executive Processor CSCI Software Implementation Requirements Document (SIRD)
D684-10500	Command & Data Handling Architecture Description Document
SSP 41152	International Standard Payload Rack Interface Requirements Document
SSP 41002	International Standard Payload Rack to NASA/ESA/NASDA Modules Interface Control Document

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3. PSIV INTEGRATION/VERIFICATION ROLE

3.1 OVERALL PAYLOAD SOFTWARE INTEGRATION AND VERIFICATION PROCESS

The overall Space Station test and verification processes for payloads are defined in the various verification plans listed in section 2. The function of verifying Payload Developer Software (PDS) is the responsibility of the Payload Experiment Developer (PED). Verification of the PDS interface with the station shall be by the Space Station Program (SSP) in cooperation with the PED. The development, integration and verification of station payload flight software and data products supporting payload operations and execution are the responsibility of the SSP. Payload interfaces to the station can assume a variety of configurations, e.g., U.S. Lab ISPR, EXPRESS, IP module ISPR, Attached, EXPRESS pallet, Facility module. The payload-to-station interfaces can be represented in a simplistic fashion as seen in figure 3-1. Payloads directly interfacing to the C&DH system will require an integration and verification process involving program testing with PSIVF and the KSC Payload Integration and Checkout Facility (PICF). Likewise, initial processing of standard controllers will follow a similar process. Payloads indirectly interfaced to the station through a standard controller will comply to the integration and verification process of the specific Payload Integration Center (PIC) or facility Payload Development Center (PDC) and will be represented analytically or with simulations in the program integration and verification activities.

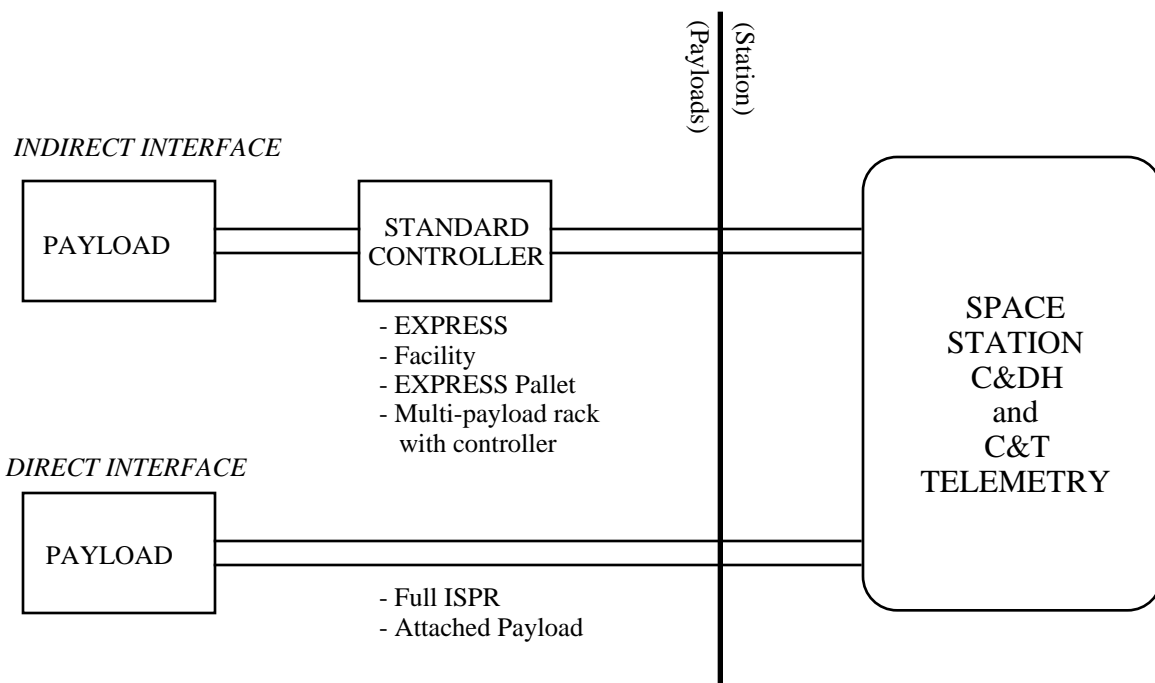


Figure 3-1 BASIC PAYLOAD INTERFACE TYPES TO STATION

The process for integrating and verifying station payload flight software and data and verifying these two types of PDS interfaces is illustrated in figures 3-2 and 3-3. Five distinct testing phases are shown in these figures, each of which may occur at different sites for different purposes. Integration and verification phase activities for payloads directly connected to the station C&DH system involve the following. The initial phase at the Payload Experiment Developer's (PED's) site will perform preliminary low-level interface testing with the Suitcase Test Environment for Payloads (STEP) and will generate requirements, flight software, and functional equivalent processors to be used in the next phase. Phase 2, Payload Software Integration and Verification,

uses the payload developers software and data, either remotely from the PED's site or locally within PSIVF, and the PSIVF test environment to verify the software interfaces of payloads to be flown. Phase 3, Station Integration and Verification, uses the payload increment products to complete station horizontal testing. Phase 4, Physical Integration and Interface Verification, represents the integration of the payload hardware and software, and the rack, and final checkout of the payload before launch. The location of the integration and final checkout may be at an approved PIC and/or at the KSC PICF. Phase 5, On-Orbit Checkout and Operation, represents checkout activities performed onboard once the flight configuration for an operational complement has been attained. Payload related anomalies identified in phases 3,4, or 5 may produce problem reports which flow back to Phase 2 for analysis and resolution.

For payloads indirectly connected to the station C&DH system, i.e. their direct command and telemetry interface is to a standard controller and the standard controller's interface to the station has already been verified, the phases involve the following. Phase 1, at the payload software development site, the PED will perform preliminary low-level interface testing and will provide requirements, specifications, and optionally simulations to the next phase. In phase 2, Payload Software Integration and Verification uses the payload provided information to develop any necessary configuration data tables, display updates, and test simulations. This information will provide the basis for representing the payload in the operational configurations maintained in PSIV. For phase 3, Station Integration and Verification, no station level testing is required. Phase 4, Physical Integration and Interface Verification, represents the final integration and checkout of the payload before launch. As stated in the previous paragraph these activities can be performed at an approved PIC and/or at the KSC PICF. Phase 5, On-Orbit Checkout and Operation, represents checkout activities performed onboard once the payload has been installed and connected to the flight standard controller. Once again, payload related anomalies identified in phases 4 or 5 may produce problem reports which flow back to Phase 2.

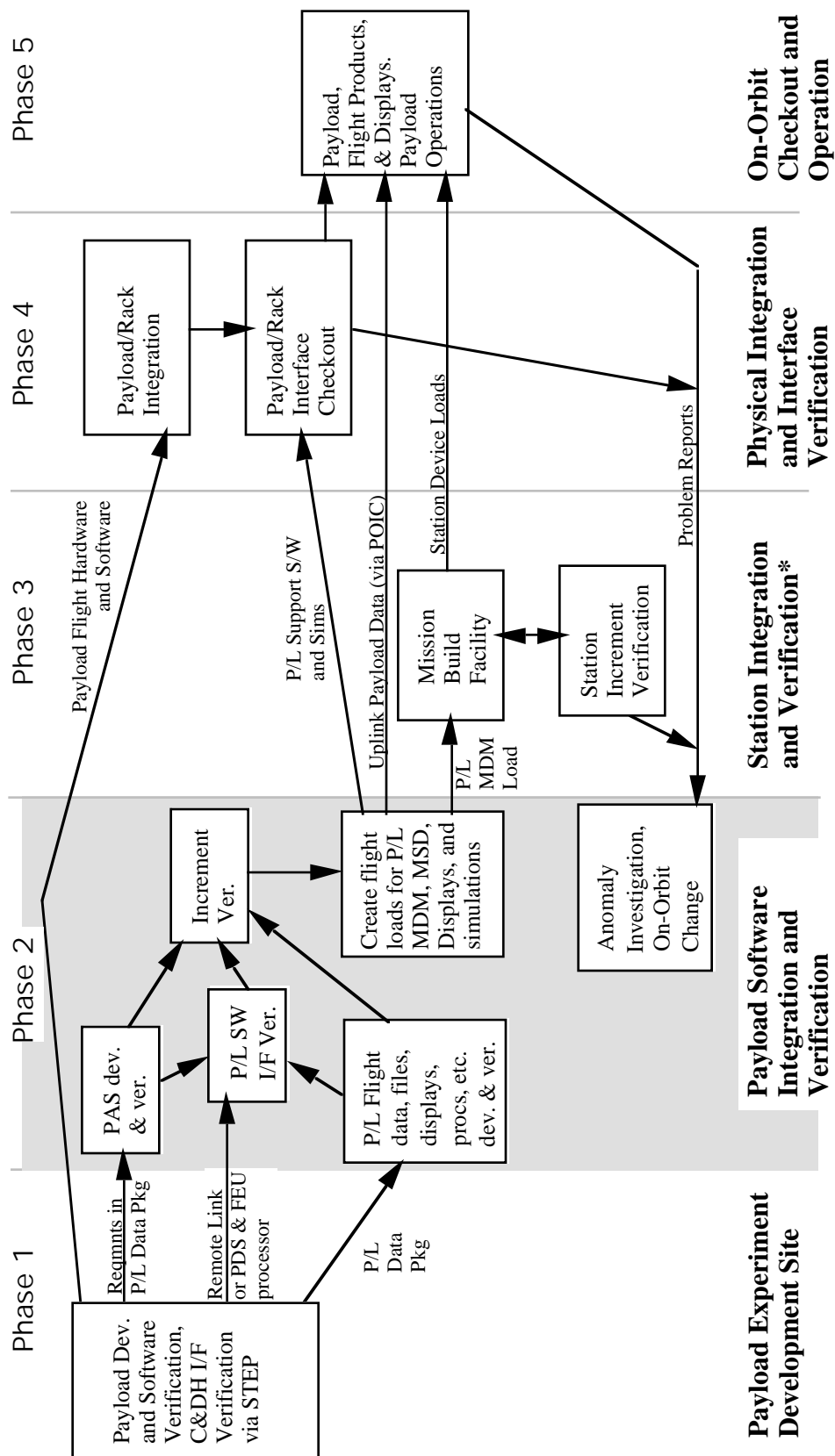


Figure 3-2 PSIV PROCESS FOR DIRECT INTERFACES

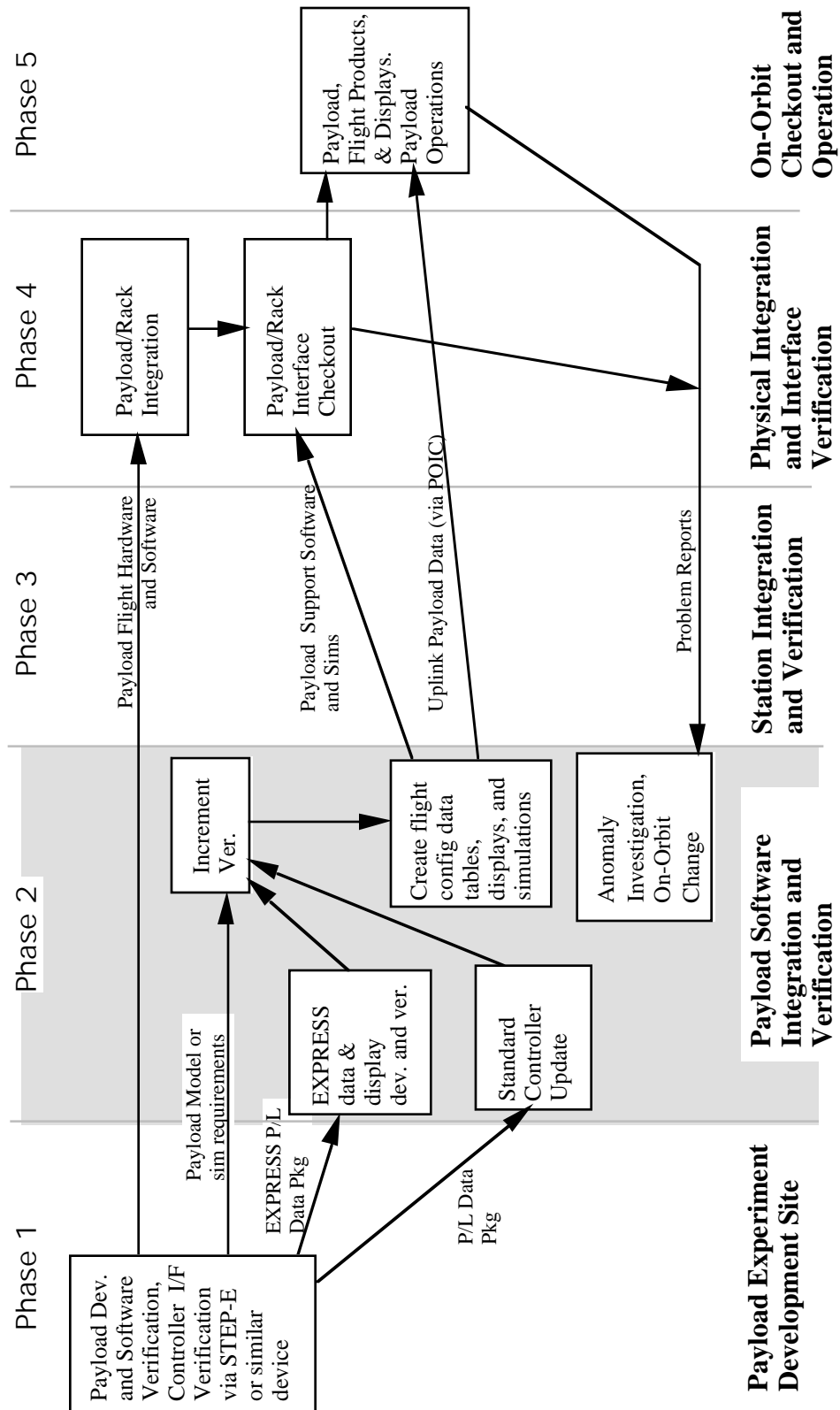


Figure 3-3 PSIV PROCESS FOR INDIRECT INTERFACES

3.1.1 PSIV Process for Direct Interfaces

3.1.1.1 PED's Site Testing - Local

Initially the PED will develop the PDS and payload hardware. The development schedule and milestones for a particular experiment are documented in Engineering Integration's Payload Data Package. Reviews, with documentation appropriate to the task, are conducted at the PED's site. The Space Station Payload Accommodations Handbook (PAH) defines the station resources, services, and interfaces available to the developer.

For payloads requiring a direct interface to C&DH, program-provided ground test equipment will be available for use. Known as the Suitcase Test Environment for Payloads (STEP), it allows the PED to test the direct C&DH interfaces of an International Standard Payload Rack (ISPR) payload to the station. These devices do not contain C&DH FEUs but will emulate the station/controller side of the interface to the payload. The device operates in both a local (stand alone) mode or in a remote (PSIVF network) mode. This section of the document describes testing locally at the PED's site utilizing a STEP for a direct C&DH interface type payload. With a STEP the PED may test the experiment PDS interface with C&DH, C&T telemetry, and basic onboard payload executive functions. Verification of station data bus protocols and generic format / content to executive functions will insure that payloads can proceed to the next level of testing and verification. A limited number of STEP devices are being developed and delivered to NASA centers. The Boeing Utilization and Operations contract Deliverable Items List (DIL) with MSFC contains the specific delivery locations and quantities. The Engineering and Operations Integration IPT will direct the allocation of unassigned devices.

Figure 3-4 shows an estimation of the level of verification that is accomplished with the STEP. The verification levels are explained in section 7, Appendix.

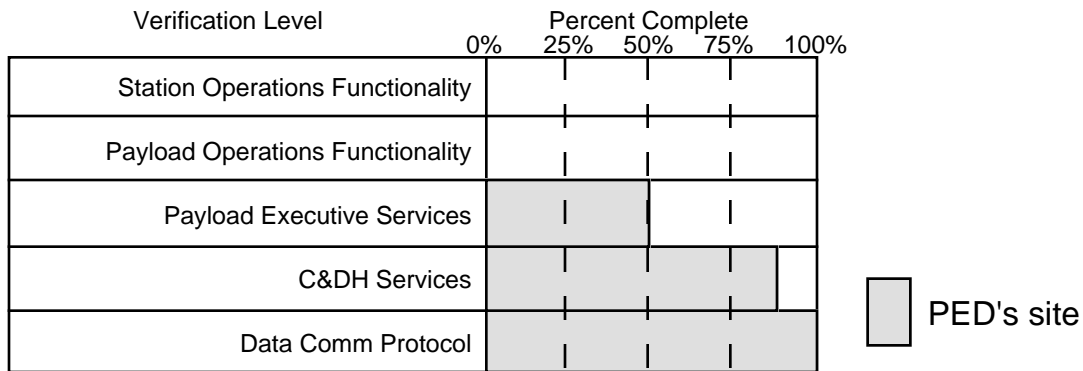


Figure 3-4 PED VERIFICATION LEVEL

The payload data communication protocol used onboard can be fully tested with the payload by the PED with the STEP. This level of testing will insure the specifications defining the basic protocol standard for 1553B, Ethernet, and the High Rate Link are met. C&DH Services refers to the specific implementation of the basic protocol standards that have been employed by C&DH and C&T devices to complete the exchange of data between the device (e.g. Payload MDM, APS, HRFM, Payload Ethernet Hub/Gateway (PEHG), PCS) and the payload. A majority of this verification can be accomplished with the STEP but since the actual FEUs and network loading are not included in the test, verification at this level cannot be considered complete. There are eight Payload Executive Services provided in the Payload MDM. These services rely on Payload Support Data, PSD, (i.e. data files, data tables, displays, and automated procedures), to function properly. The flight PSD is not available during local testing but simulated Payload MDM software and simulated PSD will allow partial verification of the payloads interface with these

services. Both payload operations and station operations functionality verification refers to the ability to test at appropriate levels such that the payload management objectives from each operation center can be satisfied. This level of testing must involve other systems and databases which are not part of local testing.

3.1.1.2 PSIV / PED's Site Testing - Remote

The PSIV prime function is to test the portion of the reconfigurable, on-board avionics dedicated to payload operations and support science mission success by verifying payload software integration for each operational complement configuration. Definitions of payload software and its components are contained in the glossary. To this end the PSIV prime function can be subdivided into three functions.

Payload Data Interface Verification :

One function of PSIV is individual payload data interface verification. During individual payload verification the integration and testing of the PDS with actual payload C&DH avionics and with the flight Payload Executive Software (PES), Payload Application Software (PAS), and Payload Support Data (PSD) is completed. Two options are available for interfacing a payload to the PSIVF test environment. First, the STEP will provide a function which will allow a payload to connect remotely to the test environment via commercial telephone lines. Secondly, the PED can provide to PSIVF a payload processor functionally equivalent unit (FEU) and the payload software executing in the processor for integration into the PSIVF test environment. Integration testing on-site at the PSIVF is not required to complete the verification process. Any exception would be worked on a case by case basis, such as PAS-to-PDS functional/interface verification. Advantages to providing hardware and software to PSIVF include the ability to test high rate data links, evaluate payload performance with the data busses and payload MDM at real data rates, and the ability for the PED to resolve any command or data problems immediately with PSD developers. In particular, the PDS interfaces to the following are tested:

- PES (including limit exception monitoring, ancillary data services)
- PAS
- Laptop Displays
- Payload Mass Storage Device (MSD)
- Timeliner (including core system interaction)
- Downlink
- Tier 1 interaction (including ground commanding)
- Time Distribution
- LSE and other Payloads

Payload Software Development :

A second function of PSIV is a software development effort. The Payload MDM contains the Payload Executive Processor (PEP) CSCI. PEP provides the PES, the MSD utilities, the automated procedure executor, the "boxcar" interface to the C&C MDM, and the low-level routines required to manage the 1553B local busses. PEP software has been designed to be mission independent, but the data, files, displays, and procedures it utilizes are reconfigured to meet mission specific requirements. The PSIV development function will create, assemble, and configure the PEP reconfigurable software items available prior to launch of a payload complement or on an "as needed" basis during operations. Some of these products will be developed and provided by the POIF, Payload Operations Integration Function. Within the Payload MDM and the Portable Computer System (PCS), the user may choose to fund the development of unique software to support payload specific operations not otherwise covered. This software is known as PAS, Payload Application Software. The PAS, if required by the PED, will either reside in the Payload MDM and be written by PSIV with requirements for the software provided by the PED or

will reside in the PCS laptop processors and be written by the PED and/or PSIV. (See glossary for definitions.)

Complement Verification :

The third function of PSIV is payload complement verification. This process will verify the overall configuration of the payload software products required on-board for the increment. Complement tests will be conducted to insure that the integrity of the shared devices, software, and networks is maintained. The Payload MDM memory, processor KIPS (thousand instructions per second), and bus throughput will be analyzed and optimized. Other payload shared resources will also be evaluated including the MSD, APS, Gateway/Hub, PCS/Displays, and Timeliner. Mission planning data will be used to develop complement test configurations/scripts.

The verification level of payload software after PSIV processing is shown in Figure 3-5. This activity significantly reduces the risk of payload software integration with the space station avionics and with the payload operations concept by verifying the payload software in a flight-like environment. C&DH services can be thoroughly tested with a combination of payload functional equivalent units operating in the PSIVF. The payload executive services are completely tested with the flight PSD products developed within PSIVF. The onboard mechanisms for accomplishing payload operations and station operations will be provided in the test environment to allow testing of operational scenarios. Additionally, the PSIVF test environment will support links with user and operations facilities, such as UOF, USOC, POIC, and provide commands to the test environment's C&C MDM simulation to conduct joint testing of systems. Hence a majority of the software verification tests can be completed for payload and station operations functionality prior to final interface testing at KSC or on-orbit.

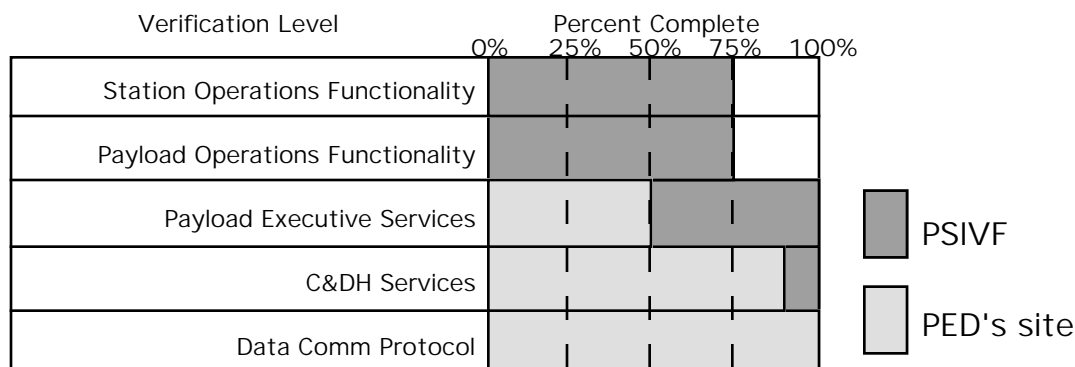


Figure 3-5 PSIV VERIFICATION LEVEL

In addition to these three primary parts of PSIV, the PSIV may be requested to assist in anomaly investigation and resolution during on-orbit payload operations. This activity could possibly involve all of the aforementioned functions of PSIV.

3.1.1.3 *Station Integration and Verification*

Station horizontal testing will be conducted in the Software Verification Facility (SVF). Payloads are isolated from the station core systems through the C&DH architecture design and through operational procedures. Since the SVF is involved solely in the verification of station software in the C&DH MDMs it does not play a direct role in the verification of a payload. Therefore no individual payload testing within the SVF is required. The Payload MDM is included in the SVF horizontal tests. An initial delivery of the Payload MDM software will be provided, via the MBF, at Utilization Flight 1 (UF-1). Subsequent deliveries will only be provided if the basic interface between the C&C MDM and Payload MDM is changed.

3.1.1.4 *Physical Integration and Interface Verification of Direct C&DH Payloads*

The program will support payload flight hardware and software integration and interface verification at an approved PIC or at the KSC PICF. Following hardware and software integration a final verification of the ISPR interfaces is conducted. These tests validate that the payload is functional in its final transfer configuration. The KSC PICF contains C&DH software capabilities similar to PSIVF described in section 4.3 in addition to a hardware test environment and a POIC workstation/database. The KSC PICF testing with actual payload flight hardware and software completes the verification testing as shown in Figure 3-6. KSC PICF supports final verification of payload flight software interfaces. The capabilities of the KSC PICF are documented in the Payload Integration Capability Specification. Similar testing can alternatively be accomplished at an approved PIC site, if adequate hardware and software test capability is provided. Integration and verification plans will be developed and specified for each payload as part of the payload data package development.

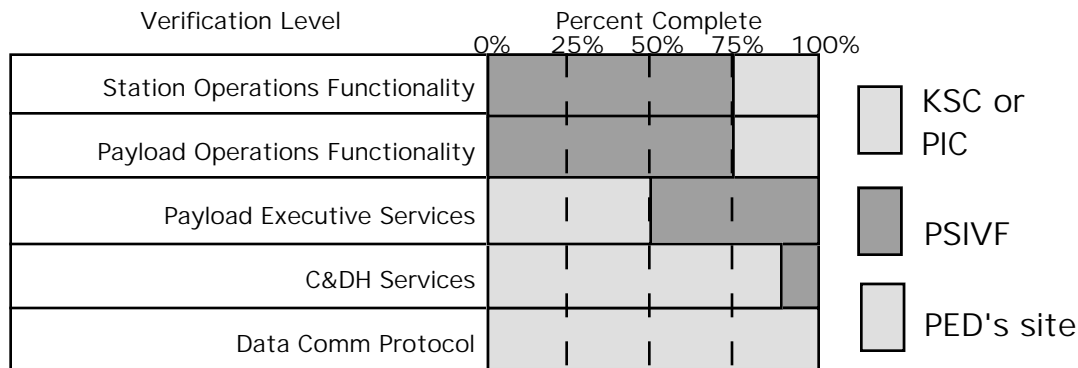


Figure 3-6 PIC OR KSC PICF VERIFICATION LEVEL

3.1.1.5 *On-Orbit Checkout / Reconfiguration*

As part of payload operations, on-orbit reconfigurations of payload software will be required to support installation of new payloads or update of exiting software configurations. The POIF will schedule the planned payload software and data updates and will allocate uplink times for performing command/file transfers to the space station. The POIF will uplink all payload software and data configurations that are resident on the Payload MDM. If removable media is utilized during reconfiguration, the POIF will schedule the appropriate crew time required to perform manual update of reconfiguration data.

Upon on-orbit installation of payloads a functional checkout test will be conducted by the POIF, supported by PSIV, as a final confirmation that the proper payload software configurations exist within the Payload MDM and that the Payload MDM to payload interfaces are operational.

During normal operations, payload operations will be conducted per the scheduled plan. In the event of any payload software related anomaly, PSIV will support POIF and payload users in evaluation and resolution of the anomaly, as requested.

3.1.2 *PSIV Process for Indirect Interfaces*

The software verification process for payloads which interface directly to a standard controller is simplified with the assumption that the standard controller has been previously integrated and

verified with the ISS C&DH system. An assumption of a "standard" controller is that no software modification is required in the controller with each integration of a payload, only data values within the controller are required to be updated. Any violation of this assumption will require the controller to go through the verification process identified previously for payloads directly interfaced to C&DH. Distinction between EXPRESS (EXpedite the PROcessing of Experiments to the Space Station) payloads and other type indirect payloads (e.g. payloads within facilities, Code X payloads) must be made since the PSIV process supports the program-developed EXPRESS controller/display configuration and sustaining engineering but not the controller configurations employed by controllers of other indirect payloads.

The program will provide a portable test device for EXPRESS rack payloads, designated as STEP-E (STEP-EXPRESS), and for EXPRESS pallet payloads, designated as STEP-EP (STEP-EXPRESS Pallet). The STEP-E will provide the ability to test command and data interfaces to the Rack Interface Controller (RIC) for EXPRESS payloads. The STEP-EP will provide a similar capability for EXPRESS Pallet payloads. Figure 3-7 illustrates the software interface verification level achieved with one of the portable suitcase testers at the PED's site. The data communication protocols can be completely verified and the interface to the standard controller can be verified to the extent possible without a functionally equivalent controller servicing multiple payloads. Most of the higher level software interfaces have already been verified via the standard controller-to-station verification process. For non-EXPRESS payloads test capabilities for individual payloads will be defined by the facility or sponsor. A similar type device (e.g. the BioTechnology Facility Mini-Payload Integration Center) may be available for these payloads to accomplish their test, integration, and verification activities.

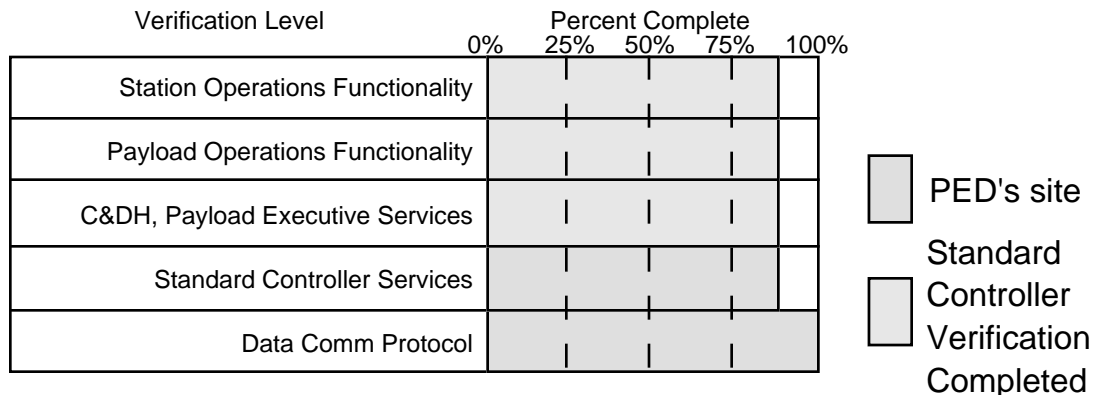


Figure 3-7 PED VERIFICATION LEVEL FOR INDIRECT C&DH PAYLOAD

The verification of software interfaces may be completed at either an approved PIC, the KSC PICF, or the PSIVF, see figure 3-8. Flight and ground configuration data is used to insure correct payload software interaction, via the standard controller, with the station payload avionics and with the payload and station operations function. At each verification level, test results shall be made available to the PED.

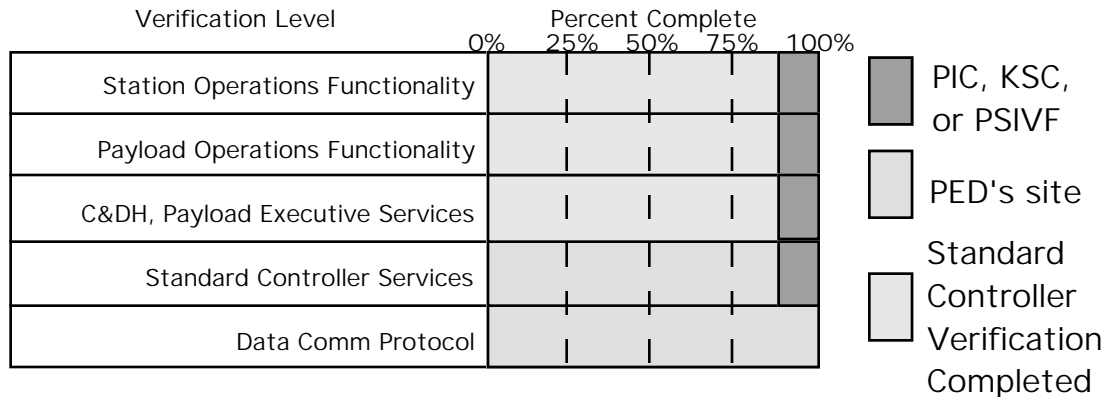


Figure 3-8 VERIFICATION LEVEL OF INDIRECT PAYLOAD COMPLETE

3.2 ORGANIZATIONAL RESPONSIBILITIES

A summary of the test, integration, and verification responsibilities is listed.

PED Responsibility

- PDS development and functionality
- Verification of PDS interface to payload hardware
- Test of PDS interface to ISS data bus/networks with STEP devices
- Support of payload-related ISS test and integration activities

MSFC PSIV Responsibility

- Development and/or integration of PSD supporting payload operations
- Payload C&DH software architecture functionality for operational configurations
- Verification of PDS functional interface with ISS payload software
- Payload representation within the SVF
- On-orbit payload software anomaly investigation and resolution via POIC
- Real-time support of payload operations

JSC SVF Responsibility

- ISS avionics
- Systems support of payload operations
- Integration of Payload MDM software within the C&C architecture

KSC PICF or Approved PIC Responsibility

- Integration of the payload flight hardware/software in on-orbit configuration
- Payload operational checkout in on-orbit configuration prior to launch
- Payload interface verification test

3.3 VERIFICATION RISKS

The primary objective of PSIV is to reduce the integration risk of payloads to the station. Ideally to fully verify an individual payload and the payload complement, the actual payload flight software with its flight hardware executing in a fully functional station avionics environment would be desirable. When the ideal test situation cannot be achieved, risks are assumed proportional to the complexity of the payload, the composition and interaction of the total payload complement, and the type of testing that can be accomplished. Some of the factors contributing to the risk level of payload software integration and verification are:

- Complexity of PDS application and its use of station avionics
- Level of PED verification
- Availability of final, flight versions of PDS to support program integration and verification tasks
- Payload flight hardware not available for payload software integration and testing
- Actual station avionics are on-orbit, ground FEUs are not identical
- Full complement of payloads not available since some may be on-orbit
- Some operational data may not be created until it is needed during the increment
- Simulations cannot fully represent real software and data
- Mission Sequences are not available for payload pre-launch integration and verification activities.

PSIV and Engineering Integration IPT will evaluate the complexity of the payload application and its software interfaces and work with the payload developer to establish the appropriate integration and verification process and document in the Payload Data Package.

Risk abatement in these areas is being addressed in a number of ways:

- High fidelity STEPs provide PED's basic station C&DH interface checkout capability
- Remote testing from the PED's development site give access to a test environment containing FEU C&DH components and increment software
- Station payload software is tested with FEU C&DH components and simulations of payload complement configurations and loading
- Standard interfaces via EXPRESS and Facility controllers isolate the payload from direct involvement with station C&DH components and simplifies checkout
- The station payload software architecture minimizes data reconfiguration requirements for each new operational complement of payloads
- Final checkout of payload flight hardware and software interfaces to station prior to transport are provided at the KSC PICF or approved payload PICs.

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4. PSIV CAPABILITY

4.1 PSIV FUNCTIONAL CAPABILITIES

Figure 4-1 shows the payload specific software, data, and files developed/used during the PSIV process that are associated with the ORUs (Orbital Replaceable Units) in the Space Station payload avionics architecture. These products represent the flight components required to support payload execution which are complement unique. These products must be developed, functionally tested with individual payloads, and integrated and verified as an operational complement.

4.1.1 *Develop Flight/Verification Products*

Referencing Figure 4-1, the PSIVF software development environment must provide the capability to support development and configuration control of the following components:

- Ada flight software running in payload related C&DH MDMs
- laptop displays
- flight software running in the laptops
- automated procedures
- MSD files
- data definitions for a variety of software applications and ORUs
- configuration data for EXPRESS rack and pallet controllers
- payload simulations used in the PSIVF and other program test and verification facilities
- PSIVF software tools

The Ada compiler and associated tools will be program approved products. It is anticipated that commercially available laptops with software will be selected by the program. Equivalent laptop and software capability will be required in the PSIVF. An automated procedure capability has been identified and PSIVF must have access to the compiler (within the HOSC) and have the on-board executor so that procedures may be created/modified and tested in a flight environment. The Payload Information Management System (PIMS) will manage the payload automated procedures utilized during payload operations and an interface between PSIVF and PIMS will be required to access baselined versions of the procedures for test purposes.

The capability to create MSD files in proper format for uplinking to the station is required in the PSIVF. Likewise the data required by the various ORUs in Figure 4-1, must be created in a suitable format for uplink to the MSD or directly to the ORU. For example, the EXPRESS RIC contains a data table that must be updated for each configuration of payloads in the rack. These data creation requirements may require PSIV to develop tools to support both the creation and verification of data files and tables.

During individual testing of payloads, complement testing of payloads, and horizontal testing with station elements, simulations will be required to represent parts of the actual flight software architecture that are unavailable. A number of PSIVF CSCIs supporting the test environment have been identified for development. These flight products will be developed in the PSIVF software development environment.

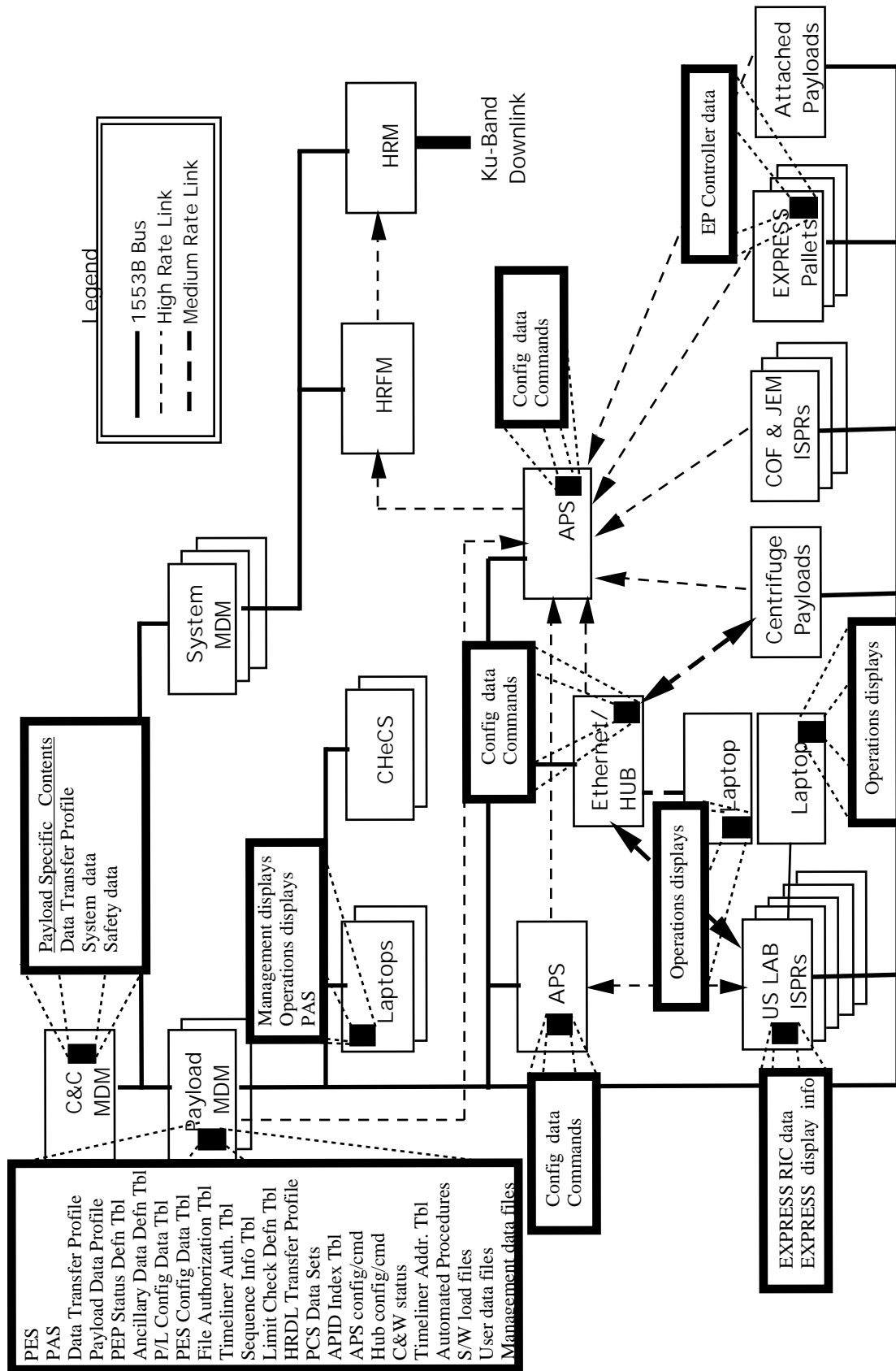


Figure 4-1 PAYLOAD PRODUCTS IN C&DH ARCHITECTURE

4.1.2 *Integrate and Verify Individual PDS Interfaces*

The PSIVF capability will be used to integrate individual PDS with management and support software (i.e. PES, PAS, and PSD), functionally test the PDS with the on-board payload avionics, and verify the PDS interface with the station. In order to use this service, the PED must provide the PDS and a functionally equivalent processor for testing within PSIVF or utilize the remote connectivity capability of the STEP. If the PED does not use this service PSIVF will develop simulations of the payload data interface for integration and testing activities. The PSIVF capability must provide a testing environment to set up specific test configurations, conduct functional tests with portions of the avionics architecture, and record and analyze test results. Functional tests will be supported by the PSIVF for individual payload testing of ground commands, ancillary data, displays, procedures, Payload MDM executive functions, telemetry, MSD utilization, and station system requests.

Ground command tests will verify capability of on-board systems to properly route commands to the correct payload, the ability of the payload to receive and understand the command, and the on-board processing of any required responses to the command. Ground commanding will require on-board definitions in the C&C MDM and Payload MDM to process and transfer the commands to the payload software. The definitions in the C&C MDM are payload independent and provide a generic data handling capability between the Payload MDM and the C&C MDM. The definitions in the Payload MDM are payload dependent and provide a complete definition of the payload's interface to C&DH. The Payload MDM definitions supporting payload commanding will be stored on the Payload MSD and read when the payload becomes active. Therefore, functional testing of ground commanding will involve verification of the payload definition files on the MSD, execution of a C&C MDM model and a Payload MDM with flight configuration data, verification of the command receipt and response by the payload, and simulation of the ground station command workstation and delivery of the command to the C&C MDM model.

The on-board ancillary data function provides core systems data and other payload data to requesting payloads. A master ancillary data packet can also be specified for transfer to the ground. Testing the access of ancillary data requires the proper ancillary set definitions on the Payload MSD which are read by the Payload MDM. The Payload MDM receives all system parameters from the C&C MDM. For on-board usage of the ancillary data, the payload will request specific ancillary data sets by name. These sets will be formed by the Payload MDM and provided to the payload on a cyclic or single shot basis. Simulations of the systems providing the data will be developed as well as simulations of payloads that might be the source of other ancillary data.

Crew interface via laptop displays requires an integrated set of data and applications on-board. For testing of displays, the display definition files must be provided, along with any data definitions that are referenced by the display. Testing will be conducted in a flight equivalent architecture and will involve the laptop device, the Payload MDM, the Payload MSD, the communications network, and the payload. To insure that displays will be fully operational on-orbit, flight configurations of all the software, files, and data will be used.

Automated procedures can be used to manage the payload complement, respond to anticipated contingency situations, and sequence payload operations. As an operations product, some procedures may only be fully defined on a real-time basis. Critical management and contingency procedures need to be tested in the PSIV prior to use on-board. As part of PSIV testing, actual flight procedures or representative procedures will be used. Procedures will be loaded and tested in processing situations similar to the flight environment. Interaction of the payload, the payload MDM, the payload MSD, and the automated procedure executor software is verified during these tests. Simulations will be developed as required to provide the level of station/payload

functionality required to give the payload software and procedures adequate and accurate software stimuli.

The payload MDM will contain executive and support functions designed to support POIC management of payloads (via Payload Executive Software). Using data created for the payload MDM, the payloads' responses to the payload MDM functions will be verified. Some of these functions are the delivery of payload health and status data, execution of shutdown and standby commands, limit exception monitoring, and delivery of the safety data required by the station from the payload. This testing will involve the payload MDM, the payload, a C&C MDM model, the payload MSD (which contains definitions used by PES), automated procedures, and the automated procedure executor.

Telemetry of data to the ground is a critical activity of payloads and the payload executive and support applications. Hence another integration and verification task will test the telemetry options used by the payload and Payload MDM to transfer payload data to the ground. Three types of telemetry paths are available to a payload: low rate through the payload MDM, medium rate through the PEHG, and high rate through the APS direct to the HRFM. These tests will insure that the proper data definitions and configurations are established for the payload to transfer data and that the data is transferred only during authorized times. Telemetry testing will involve a number of avionics components including: payload MDM, the payload, APS, PEHG, payload MDM, and HRFM. Actual hardware/software is preferred during this testing but simulations will be used where that is not possible.

The payload MSD provides storage for payload software and payload data files. The MSD is no longer a standalone device but is integrated within the payload MDM. The payload MSD must be integrated according to the requirements of the payload MSD manager. Tests of payload access to the MSD will be performed. MSD file transfers will require files and file names, authorization, and configuration data. This data will be used by the payload, payload MDM, and payload MSD and is tested to verify correct usage of the MSD.

Payload operations may require a payload interface with a core system, another payload, or with Lab Support Equipment (LSE). Configurations, authorizations, and procedures are developed to support the payload interface with other payloads, systems, and LSE. These products will be integrated into the payload software configuration for the increment. PSIVF has the capability to test and verify each payload interface requiring these products. Interfaces to other payloads and LSE accomplished via Ethernet or HRL can be tested. Simulations of payload and LSE data on 1553, Ethernet, and HRL will be part of the PSIVF. Remote capability via the STEP will allow delivery of messages from the simulations to the payload via 1553 and Ethernet. HRL interfaces at present are not tested remotely with the STEP/PSIVF combination. HRL interface testing with other payloads or LSE requires testing within PSIVF, PICF, or with other GSE equipment.

The process of integrating and verifying the PDS interfaces will also provide a verification of the flight software products developed by PSIVF (i.e. PAS and PSD) to support the payload.

4.1.3 Complement Testing

The PSIVF capability will provide for the integration and verification testing of all software related to payloads manifested for a given increment. A representation of each payload connected to the U.S. Lab Payload MDM will be required for complement verification. This may include combinations of payload hardware/software, payload software and payload FEUs, payload software models, EXPRESS controllers or EXPRESS rack / pallet simulations. Remote access to a payload via a STEP, STEP-E, or STEP-EP during complement testing can also be accommodated.

Complement testing will verify that the total set of flight software products for an operational configuration have been defined, are available, and are compatible. Each flight software product will have completed individual testing and verification suitable to the product.

Payload Operations will provide mission planning data for the increment. This data will be used to develop test configurations/scripts to exercise critical areas of operation and verify the correct execution and interaction of concurrent payload activities.

Payload avionics performance will also be analyzed during complement testing. Telemetry configuration and rates for the low, medium, and high rate downlinks will be tested. Payload MDM resource loading will be determined to insure that memory and processing rate limits are not exceeded. MDM tasking assignments and memory utilization will be tested for optimal performance. Resource configurations and limits will also be tested for other selected payload avionics components including the Payload MSD (containing Timeliner), Laptop Display, APS, PEHG, and HRFM.

The payload complement test configuration will be required to verify payload software execution with new versions of PES, C&DH, or other flight software provided by the space station program. The payload complement test configuration will also be required to investigate on-orbit payload anomalies.

Another aspect of payload complement testing is the production and delivery of payload flight software, data, and simulations to the MBF for SVF horizontal testing. The SVF will require the Payload MDM load, payload management displays, and Payload MDM local bus simulations for testing. Actual payload experiment hardware/software is not required for nominal situations in the SVF. PSIV will provide simulations of the payload software interfaces to the station. The fidelity of these simulations will be determined by the SVF test and verification requirements. Utilization flights involving nominal payload reconfigurations only are not expected to require any horizontal test activity in the SVF.

4.2 PSIV INPUT/OUTPUT PRODUCTS

Figure 4-2 shows the interfaces between PSIV and other program/user entities.

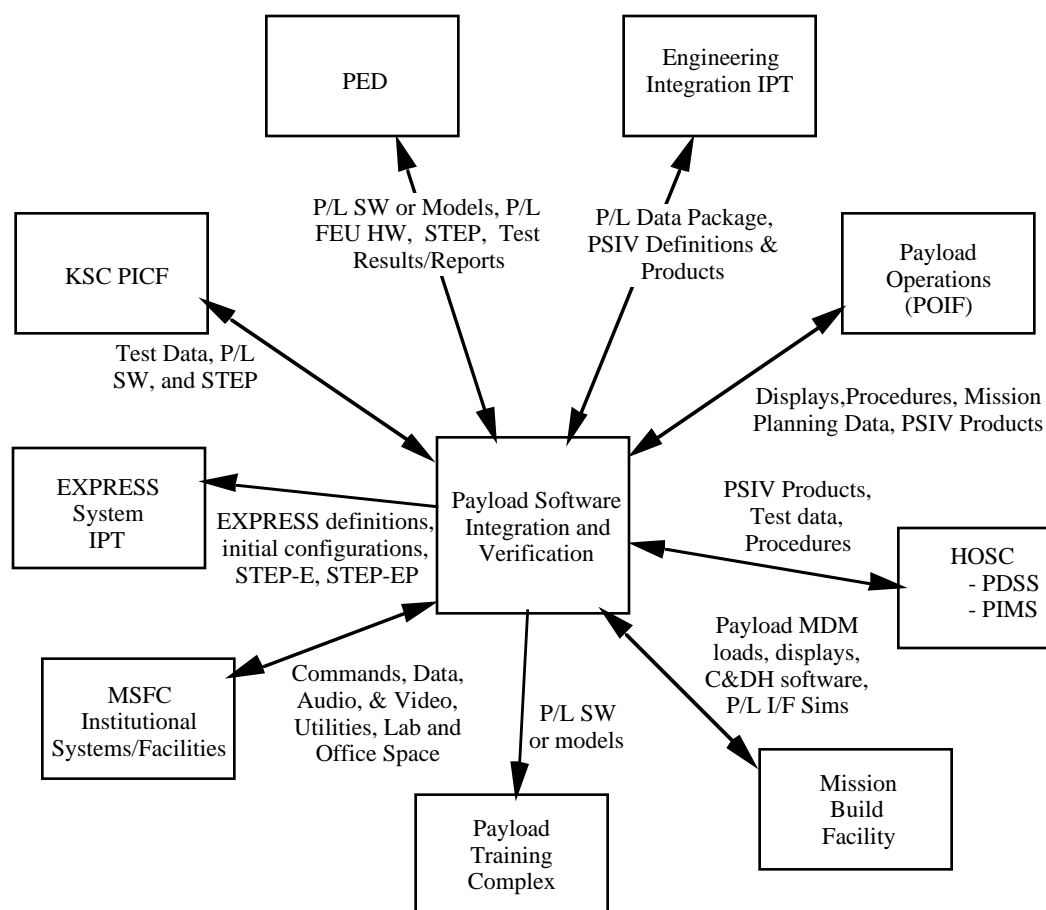


Figure 4-2 PSIV INTERFACE WITH OTHER ORGANIZATIONS

Details of the interfaces are contained in the PSIV Interface Control Plan, within individual PSIV ICDs, and via the Payload Data Package (accessible via the Payload Data Library) with regard to the PED.

4.3 PSIV ENVIRONMENT

The PSIV environment, or PSIVF, consists of three distinct environments, the PSIV Software Development Environment (PSDE), the PSIV Test Environment (PTE), and the Suitcase Test Environment for Payloads (STEP). Figure 4-3 shows the functional components of each, and the relationships between the components. The PSDE contains five functional components. The software development function encompasses the tools required to develop flight software, including laptop displays, and PSIVF ground application software. Session preparation provides the capability required to setup the test environment for a particular verification test. Session preparation includes script development, building of session loads, and creation of simulations with a generic experiment simulation builder tool. Session analysis provides the capability to retrieve logged test data, analyze, display, and generate reports of the verification tests. A configuration management system provides the important function of managing and controlling the software and hardware items for all of the active test configurations in the PSIVF, the STEP, and

versions of flight software products available for ISS onboard usage. Facility support adds the capability to develop station laptop displays and monitor and control station (MCS) displays. A distinct and dedicated set of computers and compilers comprises the PSDE computational system which provides the means to perform all the PSDE functions.

The PTE consists of five functional components and the ability to integrate PED provided FEUs or GSE into the test environment. The Host executive and simulations capability provides test session control and monitoring with test script execution and simulations of station systems and payloads. The MCS workstation provides the test operator the ability to control and monitor the test sessions. The I/O system gives the executive access to all of the standard data interface types available on orbit to ISPR and EXPRESS payloads and provides the interface between the PSIV test environment and the STEP/payload configuration. The test environment will include C&DH FEUs and EXPRESS RICs. Real-time data logging capability provides the ability to capture and archive test data.

The STEP is designed to operate in either a local or remote mode. In the local mode, the STEP simulates the command and data interfaces the payload will use in flight. Different configurations of the STEP are planned including ISPR/Attached, EXPRESS rack, and EXPRESS pallet versions. In the remote mode, the STEP provides connectivity from the payload to the PSIV test environment. The STEP includes a monitor/keyboard function to satisfy the user interface needs for control and monitoring of a test session, a processing function to simulate the different interface types, store data, and provide physical connectivity to the payload, and a modem to effect PSIV connectivity. The STEP in the remote mode will allow checkout of the payload's data interfaces to the payload MDM, PEHG, HRFM, and EXPRESS standard controllers.

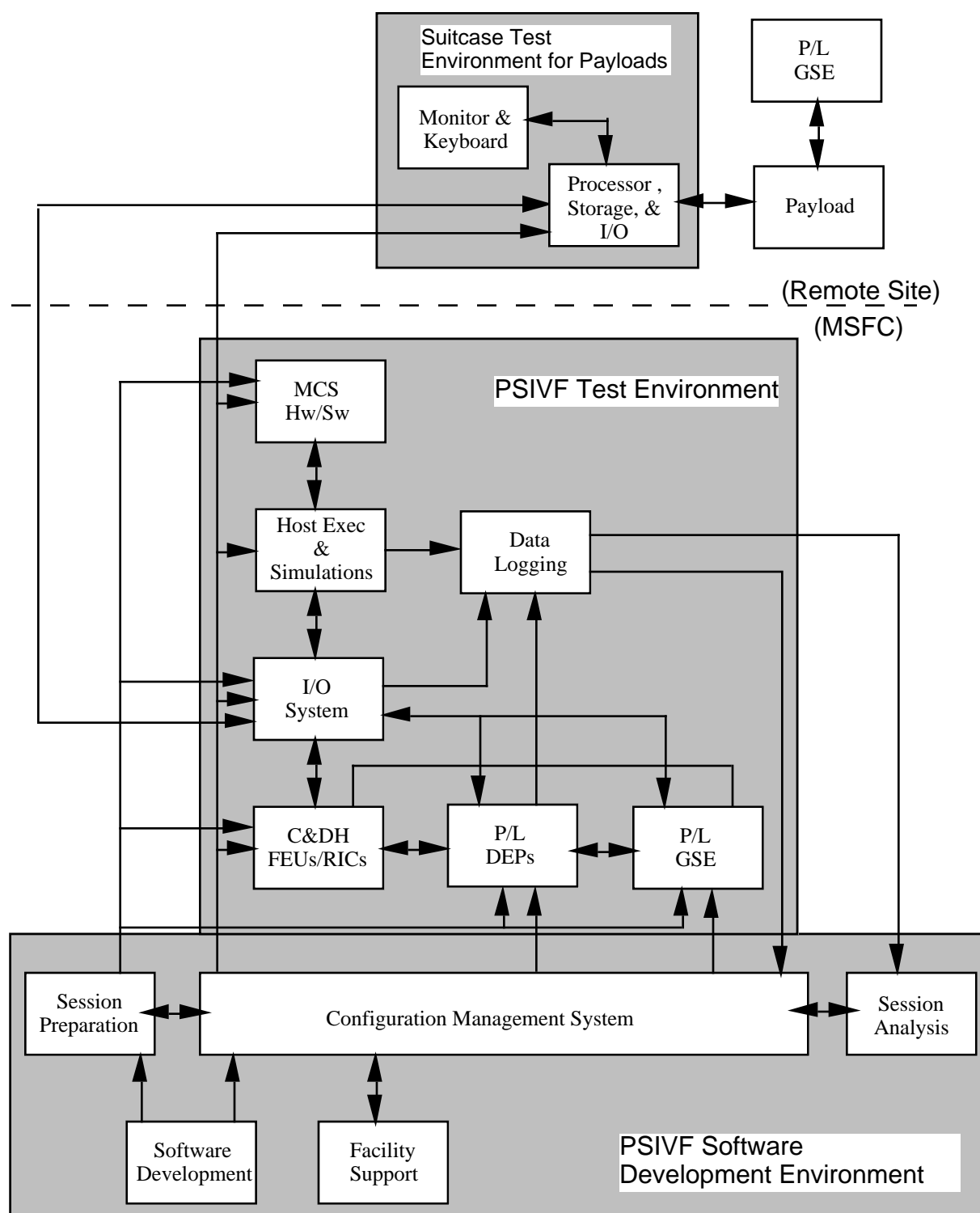


Figure 4-3 PSIVF ENVIRONMENTS

5. PSIV PROCESS TEMPLATE

PSIV is involved in development and verification tasks supporting both the prelaunch processing of payloads and configuration changes required on-orbit. The following process template descriptions only address the prelaunch processing tasks.

The process template for PSIV has been designed to support both developer and program integration and verification needs and schedules. A “standard” 24 month integration and verification template has been accepted for use on the program. Two initiatives were completed the first quarter of 1995 that have resulted in a modification of the PSIV standard template. One initiative called Short Cycle Action Team (SCAT) reduced the payload integration cycle from 24 to 6 months. The second initiative, Utilization, Operations and Training Assessment Team (UOTAT), had as a primary objective “to assess the requirements that drive the processes and to develop bold and innovative proposals that would reduce costs, enhance efficiency and performance, and eliminate program redundancies”. Some of the findings of UOTAT are :

- “Reduce the work templates associated with Cargo/Payload Integration and preflight testing to begin at L-9 months, by assembly complete time frame.”
- “Upgrade the current Suitcase Test Environment for Payload to the Payload Rack Checkout Unit level, thereby providing a higher level of interface testing for the user during the payload development cycle.”
- “Shorten and simplify program planning: reduce the Consolidated Operations and Utilization Plan from 5 to 4 years, reduce the tactical planning template from 36 to 24 months, and move the baselining of increment-specific detailed requirements (Increment Definition and Requirements Document) from I-24 to I-9 months.”

Program adoption of UOTAT recommendations are to be complete by ISS assembly complete. A nine month PSIV process template was developed to satisfy these initiatives as well as the development of a Payload Rack Checkout Unit (PRCU). The standard 24 month template is being used for UF-1, but transition plans to the nine month template are not definitized.

5.1 STANDARD PSIV TEMPLATE

The PSIV activities for payloads directly interfacing to C&DH and their relationship to Engineering Integration milestones are illustrated in Figure 5-1. Payload planning begins as early as L-60 months on the program, but details of the payload's execution requirements are not captured in preliminary form until L-36. During L-36 and L-24 Engineering Integration will work with each PED to build an initial input for the Payload Data Package containing overall payload integration and ICD information. Using this data, PSIV will begin development of any preliminary software and data requirements. Detailed execution level information may begin at L-24 and be completed by L-14 . Among the information in the Payload Data Package data directly applicable to PSIV are:

- payload command and data requirements
- software requirements for displays and PAS
- payload verification requirements

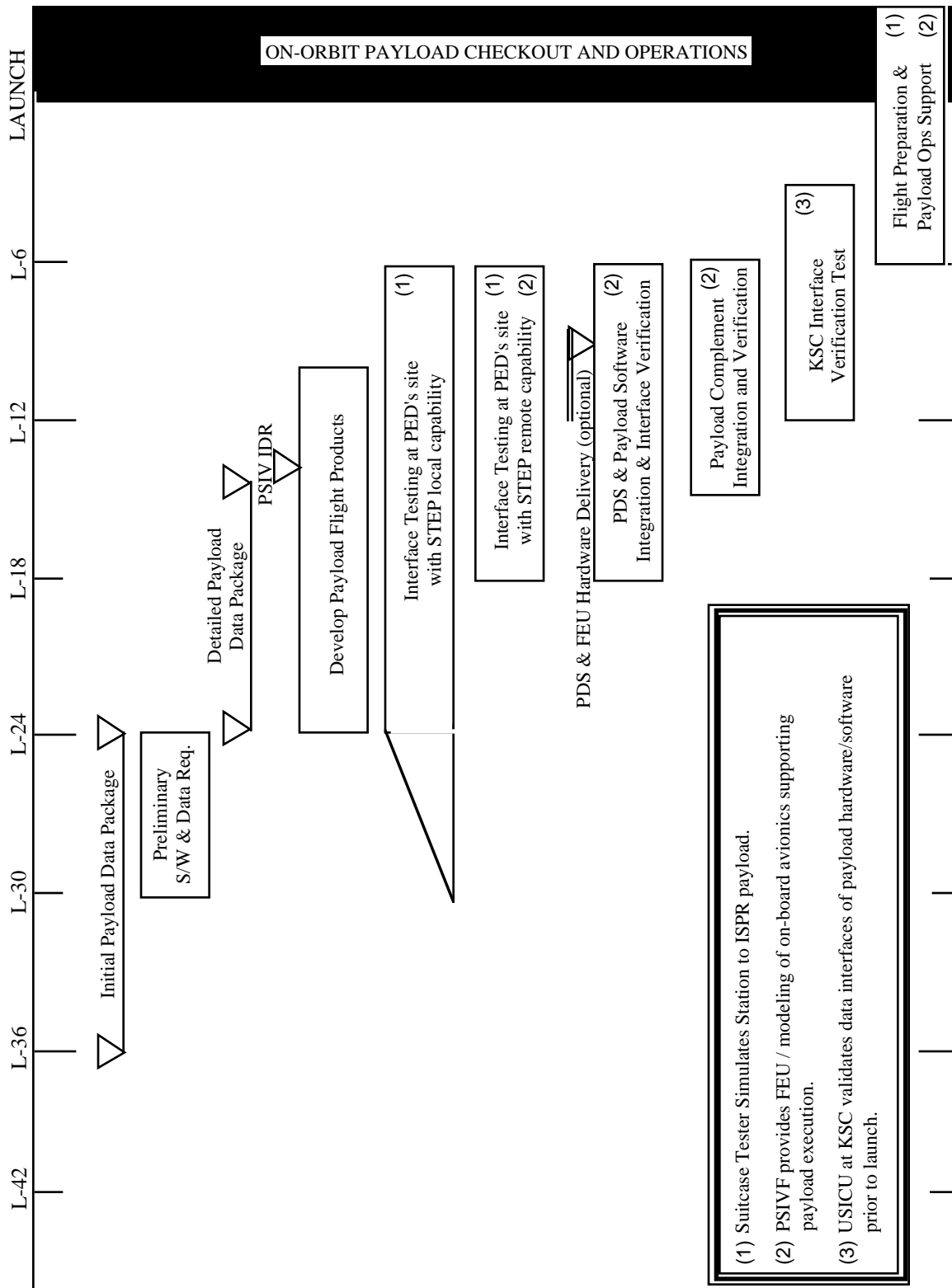


Figure 5-1 PSIV PROCESS TEMPLATE FOR DIRECT C&DH INTERFACES

From this payload information PSIV will develop the flight products supporting each payload for its initial on-orbit operational configuration. PSIV will conduct an Incremental Design Review (IDR) during the development period to insure accuracy and completeness of the products. Testing at the PED's site using the STEP in local stand alone mode will start as early as L-30 and can extend up to KSC delivery at approximately L-6. PSIV will optionally receive at its facility payload developer software and FEU hardware within the L-12 to L-9 time frame. Using the PED provided resources or the STEP remote capability, PSIV will verify the payload interfaces with the station and with the PSIV developed flight products within L-18 to L-6. Payload complement integration and verification will commence at L-14. All PSIV testing will be completed by L-6 although test support will be available via the STEP (both stand alone and remote) for all payload integration and checkout activities performed at the PICF prior to launch. Utilization of the STEP in the stand alone (local) mode or remote mode can be used by the developer in the PICF off-line labs to confirm integrity of the payload following shipping to KSC. STEP remote capability may also be used to support investigation of problems encountered during KSC Interface Verification Tests (IVT). Incremental deliveries of payload flight and test products will be provided to the MBF and PTC.

Payloads which indirectly interface to C&DH through a standard controller are handled in a simpler manner as shown in Figure 5-2. For EXPRESS payloads, the Payload Data Package is developed from L-18 to L-11. PSIV will use the data as it is available to develop the required flight definitions beginning at L-18. Verification of the EXPRESS RIC and its configuration data occurs between L-11 and L-6. In the case of non-EXPRESS payloads, "Payload Data Package" type data will be provided by each payload to the integrator of the facility or rack who will in turn update any Payload Data Package describing the total facility or rack. The integrator will develop and verify any configuration data required for the facility or rack controller. Complement testing and IVT occur as shown in figure 5-2, as the total data requirements for a rack or facility are determined.

5.2 SHORT CYCLE PSIV TEMPLATE

The short cycle template for PSIV is shown in figure 5-3. Some of the assumptions involved with this approach are to provide flight software products on an "as needed" basis and minimize IVT at KSC by moving to a "ship and shoot" concept. The STEP is still planned for availability to developers at L-30. The PRCU, which provides high fidelity simulation of the ISPR interfaces, is available at distributed user sites at L-20. The PRCU and to a lesser degree the STEP, will require configured downloads of software, data, displays, and procedures for testing. For payloads directly interfacing to the C&DH system, a complete Payload Data Package is provided by L-9. PSIV will develop the software products required for interface testing, and the payload-to-station interface testing is conducted at the PSIVF and/or the PRCU site. A preliminary version of PSIV developed flight software is available around L-6 after most interface testing is completed. Shipping of the payload to KSC may begin at L-6. Complement integration and testing is accomplished within PSIV after payloads have been shipped KSC and during MPLM integration. Since a final GO/NO GO decision is not reached until L-2, the final set of flight products is not developed and available until the new operational complement of payloads is on-board.

For EXPRESS payloads, the Payload Data Package is not provided until L-6. The EXPRESS payload software interface verification is conducted with the STEP-E or at the EXPRESS integration site. Appropriate software products are provided by PSIV to support the tests. Once the complete configuration of a rack is determined (which could include a combination of on-orbit and newly manifested payloads) the EXPRESS RIC software integration and testing is completed. A similar template may exist for other indirect, non-EXPRESS payloads that are processed by a payload integration organization different from PSIV.

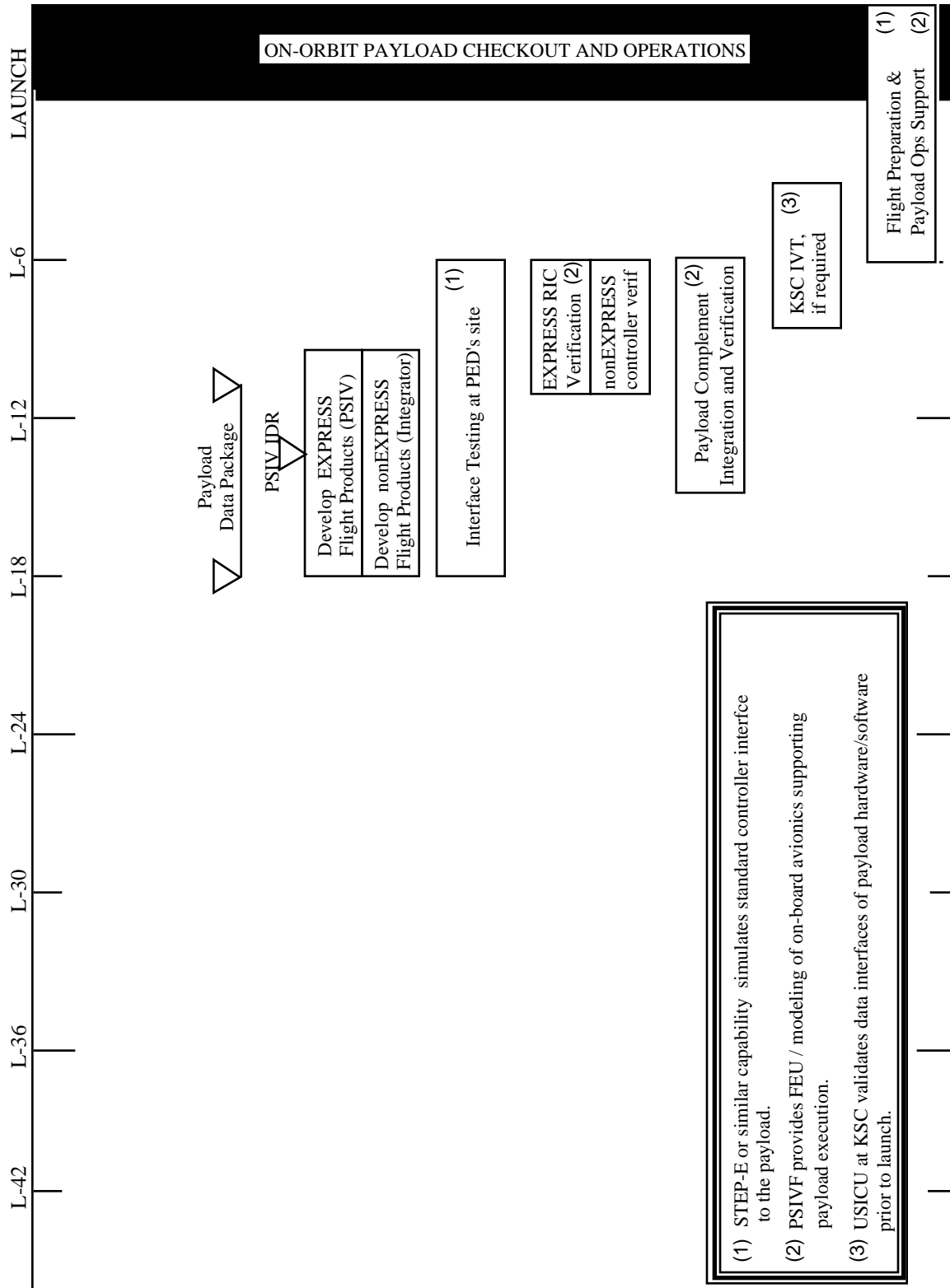


Figure 5-2 PSIV PROCESS TEMPLATE FOR INDIRECT C&DH INTERFACES

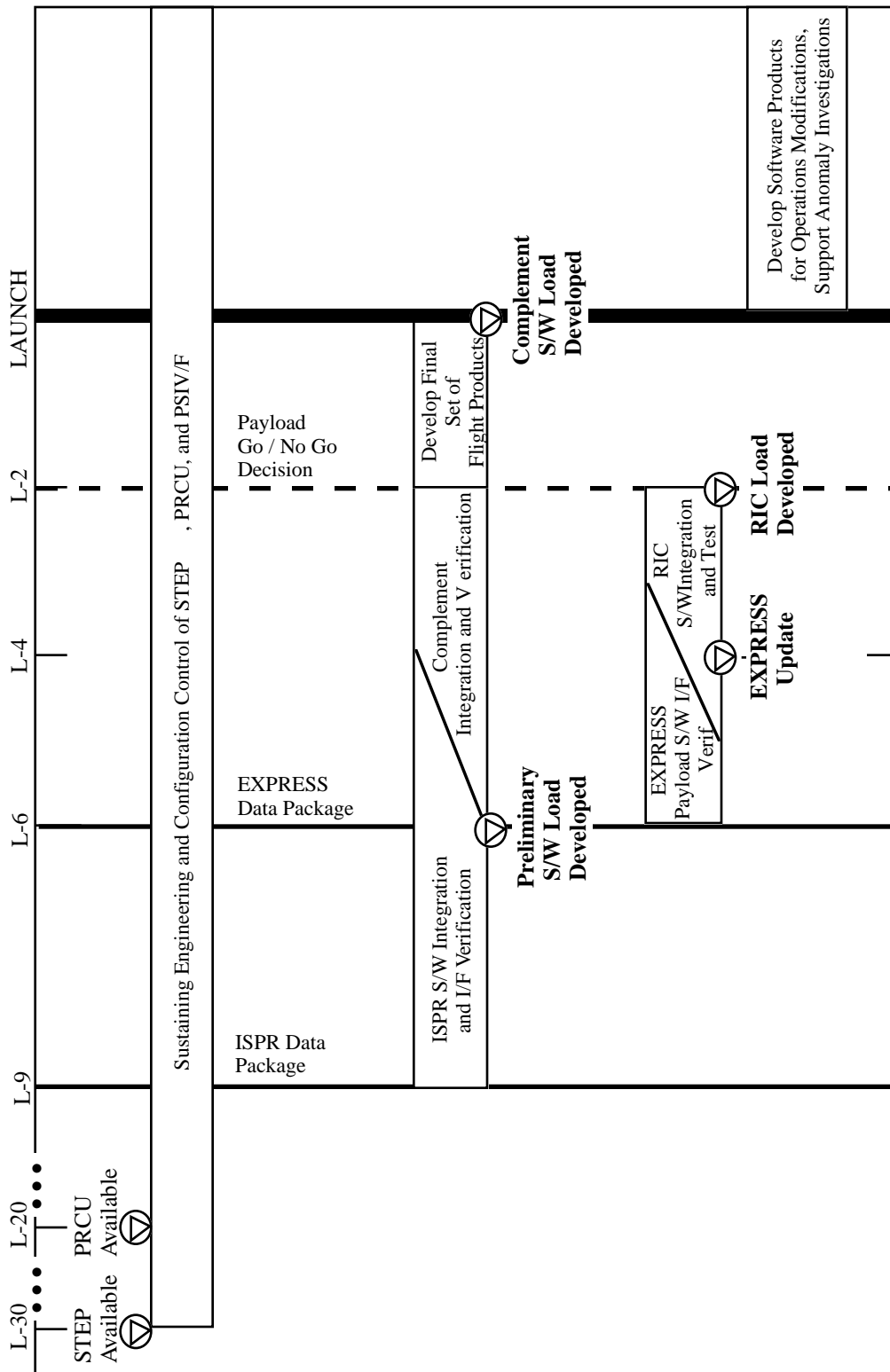


Figure 5-3 PSIV SHORT CYCLE PROCESS TEMPLATE

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6. NOTES

6.1 GLOSSARY

EXPRESS Controller Software - Each EXPRESS rack contains a Rack Interface Controller (RIC). The RIC provides a standard set of data services to EXPRESS payloads. The RIC contains ECS and data tables. For each configuration of an EXPRESS rack only the data tables must be updated to support the unique set of payloads executing in the rack.

Payload Application Software - Payload-unique software developed to perform specific data acquisition, data reduction, data processing, and data manipulation requirements for the complement of payloads on a given increment. Executes in the Payload MDM with PES. Similar to SPACELAB ECAS.

Payload Development Center - A hardware and software environment, developed and maintained by a facility class payload developer such as Gravitational Biology Facility, BioTechnology Facility, Human Research Facility, and Space Station Furnace Facility, designed to integrate and test payloads developed for operation within a space station facility.

Payload Developer Software - Software developed by the Payload Experiment Developer (PED) to execute in the PED's processor(s).

Payload Executive Software - Payload Management / Support software developed by PG-3 (Boeing Huntsville). Executes in the Payload MDM (formerly known as SDP #7 or PEP). Designed as payload system software independent of increment payload configurations that utilizes payload specific data definitions, data files, procedures, and displays. Similar to SPACELAB ECOS.

Payload Integration Center - A hardware and software environment, developed and maintained by a rack or pallet integrator such as EXPRESS, EXPRESS Pallet, and Code X, designed to integrate and test payloads developed for operation within the rack or pallet.

Payload Operations Functionality - All of the software, databases, definitions, telemetry, etc. required for the Payload Operations Integration Function (POIF) of overall management of all payloads to be performed. This includes definitions and capabilities both on the ground and on-board ISSA.

Payload Software - All on-board payload software and data supporting payload operations. Includes PES, PAS, PDS, ECS, and PSD.

Payload Support Data - All of the payload data definitions, data files, displays, and procedures stored and/or executed in station avionics devices that are used to support PES, PAS, PDS, or ECS.

Station Operations Functionality - All of the software, databases, definitions, telemetry, etc. required for the Mission Control Center - Houston (MCC-H) to perform its function of managing the overall ISSA vehicle and its mission. This includes definitions and capabilities both on the ground and on-board ISSA.

6.2 ACRONYMS

ACBSP	Assembly/Contingency Baseband Signal Processor
AIT	Analysis and Integration Team
APS	Automated Payload Switch
C&C	Command and Control
C&DH	Command and Data Handling
C&T	Communications & Tracking
COF	Columbus Orbital Facility
COTS	Commercial Off The Shelf
COU	Concept of Operations and Utilization
CSCI	Computer Software Configuration Item
DEP	Dedicated Experiment Processor
ECS	EXPRESS Controller Software
EXPRESS	EXpedite the PRocessing of Experiments to Space Station
FEU	Functional Equivalent Unit
GFE	Government Furnished Equipment
GSE	Ground Support Equipment
HOSC	Huntsville Operations Support Center
HRFM	High Rate Frame Multiplexer
HRL	High Rate Link
HRM	High Rate Multiplexer
HW	Hardware
ICD	Interface Control Document
I/F	Interface
I/O	Input / Output
IPT	Integrated Product Team
IRD	Interface Requirements Document
ISPR	International Standard Payload Rack
IVT	Interface Verification Test
JEM	Japanese Experiment Module
JSC	Johnson Space Center
KIPS	Thousand Instructions Per Second
KSC	Kennedy Space Center
LAN	Local Area Network
LSE	Lab Support Equipment
MBF	Mission Build Facility
MCC-H	Mission Control Center - Houston
MCS	Monitor and Control Station
MDM	Multiplexer/Demultiplexer
MSD	Mass Storage Device
ORU	Orbital Replaceable Unit

PAH	Payload Accommodations Handbook
PAS	Payload Application Software
PCS	Portable Computer System
PDS	Payload Developer Software
PDSS	Payload Data Services System
PED	Payload Experiment Developer
PEHG	Payload Ethernet Hub/Gateway
PEP	Payload Executive Processor
PES	Payload Executive Software
PG-3	Product Group-3
PIC	Payload Integration Center
PICF	Payload Integration and Checkout Facility
PID	Prime Item Development
PIM	Payload Integration Manager
PIMS	Payload Information Management System
PIP	Payload Integration Plan
P/L	Payload
POIC	Payload Operations Integration Center
POIF	Payload Operations Integration Function
PRCU	Payload Rack Checkout Unit
PSD	Payload Support Data
PSDE	PSIV Software Development Environment
PSIMP	Payload Software Integration Management Plan
PSIV	Payload Software Integration and Verification
PSIVF	Payload Software Integration and Verification Facility
PTC	Payload Training Complex
PTE	Payload Test Environment
PVPP	Payload Verification Program Policy
RIC	Rack Interface Controller
SCAT	Short Cycle Action Team
SIM	Simulation
SOW	Statement of Work
SS	Space Station
SSP	Space Station Program
STEP	Suitcase Test Environment for Payloads
STEP-E	Suitcase Test Environment for Payloads - EXPRESS
STEP-EP	Suitcase Test Environment for Payloads - EXPRESS Pallet
SVF	Software Verification Facility
SW	Software
TBS	To Be Supplied
UF	Utilization Flight
UOF	User Operations Facility
UOTAT	Utilization, Operations and Training Assessment Team

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7. APPENDIX

The following items are verified at each verification level:

Data Communications Protocol

MIL-STD-1553B

IEEE 802.3 / 10 BASE T

TAXI

C&DH Services

PEP PIFS (payload interface service)

PCS application interface

APS / HRFM application interface

PEHG application interface

CCSDS packet standards for on-orbit and telemetry

Payload Executive Software

Health and Status Service

Procedure Execution Service

MSD Services

Ancillary Data Service

Low Rate Telemetry Service

Operational Control Service

Limit Exception Service

Payload Commanding Service

Payload Operations

Ground and On-orbit software and data consistencies for POIC management

Station Operations

Ground and On-orbit software and data consistencies for MCC-H management

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